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# Secure Integration of eBusiness Processes in the Extended-Enterprise

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## Abstract

*The new unit of competition is no longer the individual firm but rather the extended-enterprise. It has long been recognized that information security and system integration are among the key issues for IT executives. We posit that these issues still remain open and they are exacerbated by the fact that highly competitive enterprises operate in an environment characterized by distributed and heterogeneous information systems and heterogeneous information and knowledge resources. Following the design science paradigm, we propose a design artifact that allows for formally represented knowledge to be securely shared across the extended-enterprise. The effective deployment of semantic web technologies would enable the proposed IT artifact to support the dependencies among multiple knowledge resources for effective eBusiness processes the extended-enterprise.*

**Keywords:** Extended-enterprise, Semantic Web, Knowledge Representation, Role Based Access Control, Design Science, Security, Knowledge Exchange.

## Introduction

The traditional resource based view of the firm (Wernerfelt, 1984) considers the individual firm as the basic unit of competition. In this research we broaden our focus to the extended enterprise, where a local firm is embedded in a network of collaborating firms that have the common goal of creating valuable customer propositions. This view is consistent with Porter's framework (1985) of value activities and value chain and it is consistent with Sawhney and Parikh's view (2001) of inter-organizational processes that provide complementary services through networks of collaborating organizations. For this research we adopt Browne's (1998) concept of the extended enterprise, which states that an extended enterprise can be defined as a collection of independent, heterogeneous entities working closely together in order to produce an integrated product and/or service, in whose commercial success they all have a vested interest.

Information flows and activity coordination among business partners of an extended enterprise can be negatively affected by fragmented IT infrastructure (Barua et al. 2004; Sambamurthy et al. 2003). In establishing an agenda for IT research in heterogeneous and distributed environments, March et al. (2000) recognize the complexity involved in sharing knowledge in business organizations and explain that semantic interoperability is one of the most important research issues and technical challenges. Likewise, it has been recognized that information security and system integration are among the key issues for IT executives (Luftman et al., 2005). We posit that those issues remain open and are exacerbated by the fact that highly competitive enterprises operate in an environment characterized by distributed and heterogeneous information systems and heterogeneous information and knowledge resources.

Information and knowledge resources are distributed within and across organizations and it has been recognized that knowledge resources must be shared to be useful and applicable (Raghu and Vinze, 2005). Cooperative inter-organizational

knowledge sharing through the extended enterprise can increase partners' knowledge base and competitiveness (Loebecke et al. 1999; Lorange, 1996). This view is consistent with the knowledge based theory of the firm (Grant, 1996). Here, we take the view that information and knowledge sharing in an extended enterprise occurs in a Business Process context (Raghu and Vinze, 2007; Singh and Salam, 2006). IT must integrate and secure end-to-end business processes across organizational boundaries (Luftman et al., 2005). Coordinating complex inter-organizational processes requires knowledge-driven coordination structures in an extended enterprise to determine knowledge sources and decision authority (Anand and Mendelson, 1997).

Despite the aforementioned importance of inter-organizational information sharing, research on the security of distributed business processes does not provide a holistic business process perspective to secure information and knowledge sharing (Oh and Park, 2003). Local security policies are not designed for distributed resource sharing while global policies do not consider impediments to access control of local resources (Sandhu et al., 1996). Centralized mechanisms fail to capture the distributed nature of systems support required for inter-organizational business processes. Extant literature does not *explicitly* consider or systematically represent *component knowledge* of resources such as description of skills and product knowledge; *process knowledge* including process workflow models; and *security knowledge* of authorized access for activities to resources within and across organizations. A holistic consideration of these in the design of information systems to support secure and coordinated business processes is critical for an extended enterprise.

This research attempts to fill the gap described above by designing an IT artifact that addresses the security of information and knowledge resources and system integration issues; so that information and knowledge exchange in an extended enterprise can be seamlessly and securely accomplished. To develop this research, we adopt the design science paradigm as a research method. This paper is organized following design science research guidelines (Hevner et al., 2004; Walls et al. 1992). The following section presents the research method used, and Section-III explains the theoretical foundations and the kernel theories for the design product and design process. Section-IV describes the meta-design of the IT artifact. In section-V, we evaluate the proposed IT artifact using a demand forecasting process model from a large organization. Finally, we present concluding remarks.

## Design Theory and the Design Science Paradigm

Design science research addresses classes of problems that solve relevant and unsolved problems, or solve problems in a more effective and efficient manner (Hevner et al. 2004). Due to the novelty of many design-research problems, an optimal solution may not always be possible, leaving a *satisficing* (Simon, 1996) solution acceptable (Hevner et al., 2004). Design Theory is prescriptive theory that integrates normative and descriptive theories into design paths to produce the artifact (Walls et al., 1992). The output of design science research includes a better set of theories through enhanced knowledge of relationships between components of the design artifact. We integrate the perspectives of Walls et al. (1992), Hevner et al. (2004), March and Smith (1995) and Vaishnavi et al (2006) in developing an IT artifact that addresses the security of information and knowledge resources, IT complexity, and system integration issues; so that knowledge exchange in an extended enterprise can be seamlessly and securely accomplished.

We combine theoretical foundation from the application domain with relevant IS Domain knowledge to design our IT artifact. Specifically, to identify the meta-requirements of the proposed IT artifact, we draw from the kernel theories of business process and Inter-organizational workflow (van der Aalst and Kumar, 2003; WfMC, 1996); coordination theory (Malone et al., 2003; Kishore et al., 2006; van der Aalst and Kumar, 2003); access control (The National Institute of Standards and Technology (NIST), 2004; Oh and Park, 2003, Sandhu et al., 1996); agency theory (Jensen and Meckling, 1976); resource based view of the firm (Wernerfelt, 1984); value chain and networks of collaborating organizations (Porter, 1985; Sawhney and Parikh, 2001); and knowledge based view of the firm (Grant, 1996). In addition, to develop the meta-design of our IT artifact we then apply semantic web technologies, which include include: i) *Ontologies*, which represent structured and codified knowledge about the concepts, relationships and constraints for a domain of interest; ii) *Knowledge Representation (KR)* for structured collections of information and inference rules for automated reasoning in a single system; and iii) *Intelligent Agents* to collect content from diverse sources and exchange data enriched with semantics (Berners-Lee et al., 2001).

Hevner et al. (2004) propose a conceptual framework for understanding, executing, and evaluating IS research combining behavioral-science and design-science paradigms. Basically, Hevner et al. (2004) propose a research cycle that involves the identification of a relevant business problem that is solved by designing an IT artifact, which is evaluated using the appropriate methods and context; so that additions to the IS knowledge base and environment can be achieved. Now, we apply the framework of Hevner et al. (2004) for information system research to show (Figure 1) how our research is both relevant and rigorous and contributes to the IS knowledge base by solving an important kind of business problem.

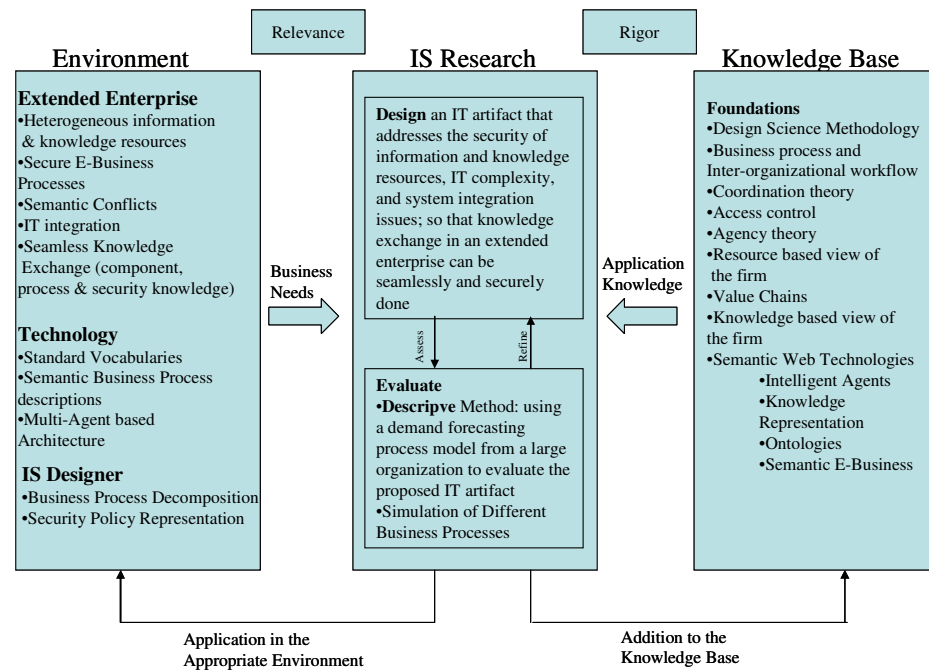


Figure 1. Summary of Relevance// Rigor of this Research (Adapted from Hevner et al. 2004)

## Theoretical Foundations

### *Theoretical Foundations from the Application Domain*

Integrating knowledge resources across an extended-enterprise requires secure access to preserve local SAC requirements and autonomy. Activities of organizations are inter-connected and require multiple constraints for appropriate access control to information resources (Oh and Park, 2003). Current inter-organizational integration models suffer from a lack of knowledge sharing in a secure coordinated manner (Singh, et al., 2005). The proposed IT artifact incorporates coordination of *component knowledge*, *process knowledge* and *security knowledge* for integrated inter-organizational eBusiness processes of an extended enterprise. Here we focus on three types of knowledge namely:

- Component knowledge* including descriptions of skills, technologies, resources, consumer and product knowledge, is amenable to knowledge exchange (Tallman, et al., 2004).
- Process knowledge* is typically embedded in the process models of workflow management systems or exists as coordination knowledge among human agents to coordinate complex processes (van der Aalst and Kumar, 2003).
- Security Knowledge* relates to access control mechanisms used to permit or deny access to knowledge resources in distributed systems (Sandhu 1996; Oh and Park 2003).

As organizations become increasingly distributed, their reliance on inter-organizational information and knowledge flows with partner organizations is integral to eBusiness processes. Here workflows establish the logical order of execution between individual business activities in business processes within and across organizations. Inter-organizational workflow in an extended enterprise generally involves communications among business partners whose information systems are different. In addition, such communications are made difficult because there is not a single way to represent the information and knowledge to be exchanged and because partners' process information and knowledge are hidden from each other (van der Aalst and Kumar. 2003).

As mentioned earlier, coordination of complex inter-organizational processes requires knowledge-driven coordination structures in an extended enterprise to determine knowledge sources and decision authority (Anand and Mendelson, 1997). Malone *et al.* (1999) define coordination as "managing dependencies among activities" and provide a taxonomy of dependencies among activities and resources. We use an activity-resource dependency where *dependencies exist as sharing, flow or fit dependency with another activity through a resource* (Singh and Salam, 2006). Here, direct dependencies between activities do not exist. An activity may consume or produce a resource; but it cannot produce or consume another activity. This is consistent with Malone *et al.* (2003) and is a simplification of the activity dependencies in van der Aalst and Kumar (2003). This activity-resource dependency coordination is also supported by analysis of Porter's framework (1985) of value activities in a value-chain. Here, security is an integral part of the value activities of the extended enterprise.

Several security access control models including the discretionary access control (DAC) model, the mandatory access control (MAC) model, the role-based access control (RBAC) model, and the task-role-based access control (T-RBAC) have been proposed to secure distributed applications. In this paper, we adopt RBAC (Sandhu et al., 1996) as a mechanism to provide secure knowledge exchange in the extended enterprise. The primary benefit of RBAC over previous security mechanisms such as mandatory access control and discretionary access control is the ability of RBAC to accommodate the changing roles of users. RBAC adds *roles* as a layer of abstraction to simplify the association between *users/actors* (agents) and *permission*. Access control policies that specify users' permissions to specific system resources are defined through the relationships among users, roles and permissions. Sandhu et al. (1996) define a family of RBAC models that include role hierarchies and constraints that allow system administrators to assign users permissions to system resources using roles. Roles are organized and managed using role hierarchies that define the inheritance structure of roles. Role hierarchies for an organization commonly reflect the organizational structures and the hierarchy of responsibility in the organization. Constraints add pragmatic consideration and exceptions to the relationships role hierarchies and are useful tools in implementing organizational policy for access to system resources (Park et. al, 2001).

A central problem of extended-enterprise knowledge sharing is to determine *how much* and *what knowledge* should be shared, *when*, *with whom*, and *under what conditions* (Loebecke et al., 1999). Simpler, codified and explicit *component knowledge* is amenable to knowledge exchange (Tallman et al., 2004). Explicit declarative and machine-interpretable knowledge represented using standards-based knowledge representation (KR) languages allows processing by automated reasoning mechanisms. While all knowledge cannot be explicated and be effectively represented and reasoned by using decidable and complete computational techniques; it is useful to focus on explicit, declarative KR to build useful knowledge-based systems. Newell (1982) provides a functional view of knowledge as "*whatever can be ascribed to an agent, such that its behavior can be computed according to the principle of rationality.*" This provides a basis for functional knowledge management by agents (human and software) using explicit, declarative knowledge that is processed using reasoning mechanisms to reach useful inferences.

### ***Theoretical Foundations from the IS Knowledge Domain***

In this research, we apply semantic web technologies in conjunction with the vision of Semantic eBusiness to establish the technical foundation for the development of the proposed IT artifact. Developments in semantic technologies make semantic web content unambiguously computer-interpretable and amenable to agent interoperability and automated reasoning techniques (McIlraith et. al., 2001). Ontology-based representation of eBusiness processes lends specificity to representation of relevant knowledge domains. This allows for knowledge to be *interpreted by software and shared using automated reasoning mechanisms to reach useful inferences*. Built on a Resource Description Framework (RDF) and Description Logics (DL), the Web Ontology Language (OWL) is a W3C standard for semantic knowledge representation. Web Services and Web Services Architecture provide envelope and transport mechanisms for information and knowledge exchange. Together, these technologies provide semantic knowledge representation and exchange mechanisms for developing secure semantic eBusiness Processes.

The Semantic Web is an extension of the existing Worldwide Web in which information is given "*well-defined meaning*" to allow machines to "*process and understand*" the information presented to them (Berners-Lee et al. 2001). The Semantic Web vision comprises *Ontologies* for common semantics of representation and ways to interpret ontology; *Knowledge Representation (KR)* for structured collections of information and inference rules for automated reasoning in a single system; and *Intelligent Agents* to collect content from diverse sources and exchange data enriched with semantics (Berners-Lee et al., 2001).

Singh et al. (2005) define Semantic eBusiness as "*an approach to managing knowledge for coordination of eBusiness processes through the systematic application of Semantic Web Technologies*". Semantic eBusiness leverages Semantic Web technologies and concepts to support the transparent flow of semantically enriched information and knowledge and enable collaborative eBusiness processes within and across organizational boundaries. In addition, the Semantic Web aids intelligent agents to organize, store, retrieve, search, and match information and knowledge for effective collaboration among Semantic eBusiness participants. The Semantic eBusiness vision provides organizations the means to design collaborative and integrative, inter- and intra-organizational eBusiness processes, and systems founded upon the seamless exchange of knowledge among trusted business partners. Therefore, Semantic eBusiness lays the groundwork for developing secure semantic eBusiness processes for the extended enterprise.

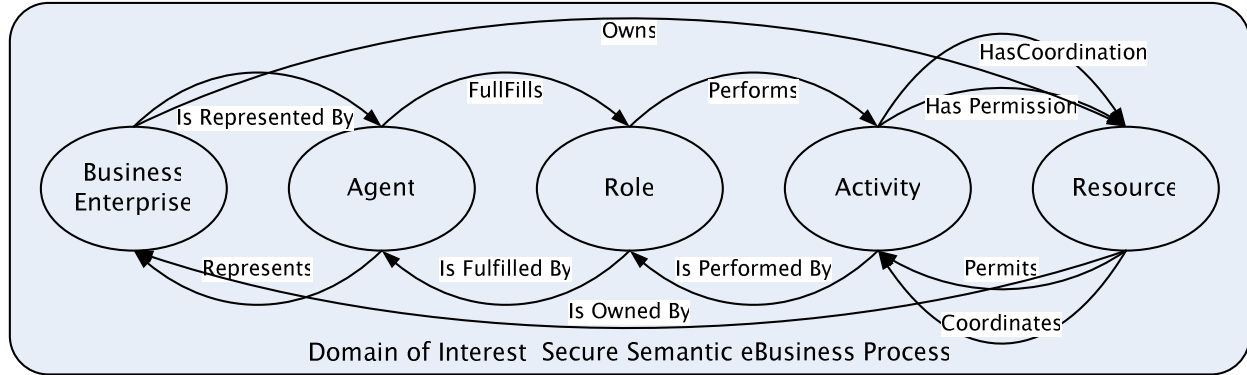
### **Meta Design**

Analysis of kernel theories and meta-requirements for the proposed IT artifact, presented in the previous section, allows us to model concepts and their relationships, including access control relationships that satisfy the requirements. We conceptualize our universe of discourse as:

*In an extended enterprise's eBusiness process, a Business Enterprise authorizes representation to an actor or Agent to fulfill a Role, which performs Activities that have access permissions to resources.*

*Resources permit activities performed by Roles fulfilled by Agents that represent Business Enterprises, engaged in an eBusiness Process.*

The design-theoretic conceptualization of a secure semantic eBusiness process, including constructs and relationships derived from the analysis of the kernel theories and posited to meet the meta-requirements is shown in figure 2.



**Figure 2. The Secure Semantic eBusiness Process for the Extended Enterprise (adopted from Singh and Salam 2006)**

DL formal representation of the meta-design for our IT artifact describes semantic schema of a domain through specifications of complex concepts and relation expressions built upon atomic concepts and relations. Constructs are represented with the *concept construct*, a unary predicate, while relationships between constructs are the *relations construct*, which may be n-ary. Subsumption hierarchies of primitive and derived concepts and relationships express specialized relationships between derived concepts. Subsumption and disjointness operations on descriptions use the hierarchy to suggest comparable concepts that appear equivalent, disjoint or overlapping. A variety of operators, including generalize, specialize or delete, refine the hierarchy.  $R^{-}$  is the inverse of relationship  $R$ . These concepts and relationships are used to define terminological axioms to develop the knowledge representation for our IT artifact that can be represented using OWL-D. We refer the interested reader to Singh and Salam (2006) for a detail of the DL of concepts and relationships for the proposed IT artifact.

A resource is related to business activities through the operations that it permits business activities to perform. A resource specifies the permissions specific to business activities. Therefore if a business activity has permission if it is allowed to perform an operation on a resource. Permits and HasPermission are inverse relationships.

$Resource \exists (Permits.BusinessActivity)$   
 $BusinessActivity \exists (HasPermission.Resource)$

Activities depend on resources and require coordination mechanisms in order to resolve dependencies. A resource is related to an activity by the Coordinates relationship.

$Resource \exists (Coordinates.BusinessActivity)$   
 $BusinessActivity \exists (HasCoordination.Resource)$

Dependencies among multiple resources and multiple activities are shown in Table 1 adapted from Malone et al. (2003). Here, Malone et al. (2003) defines resources as anything that can be used or affected by activities.

**Table 1. Dependencies among multiple resources and multiple activities (Adapted from Malone et al. 2003)**

Dependency Type	Description
<i>Flow Dependency</i>	Typical of producer/consumer dependence where resources may be produced or consumed by business activities.
<i>Fit Dependency</i>	Two activities result in a common resource, hence the notion of 'fit' dependency among activities and output resources.
<i>Sharing Dependency</i>	Two activities have the same resource as a precondition.

DL SHIQ, allows inheritance hierarchies of relationships. We use the inheritance hierarchies to express the coordinates relationship as *CoordinatesFlow*, *CoordinatesFit*, or *CoordinatesSharing* relationships.

$$\begin{aligned}
 &Coordinates \subseteq \\
 &\quad CoordinatesFlow \\
 &\quad CoordinatesFit \\
 &\quad CoordinatesSharing
 \end{aligned}$$

We utilize the inheritance hierarchy of the Coordinates relationship to develop a complex description of the relationship between Resources and Business Activities.

$$\begin{aligned}
 &Resource \exists \\
 &\quad (\geq 0 \text{ } CoordinatesFlow.BusinessActivity) \wedge \\
 &\quad (\geq 0 \text{ } CoordinatesFit.BusinessActivity) \wedge \\
 &\quad (\geq 0 \text{ } CoordinatesSharing.BusinessActivity)
 \end{aligned}$$

Coordination requirements lead to specific permissions on resources. A resource is related to an activity through the abstract Permits relationship that is specialized as *PermitRead*, *PermitWrite*, *PermitCreate* or *PermitDelete* relationships.

$$\begin{aligned}
 &Permits \subseteq \\
 &\quad PermitRead \\
 &\quad PermitWrite \\
 &\quad PermitCreate \\
 &\quad PermitDelete
 \end{aligned}$$

We use the inheritance hierarchy of the Permits relationship to develop a more description of the relationship between Resources and Business Activities.

$$\begin{aligned}
 &Resource \exists \\
 &\quad (\geq 0 \text{ } PermitsRead.BusinessActivity) \\
 &\quad (\geq 0 \text{ } PermitsWrite.BusinessActivity) \\
 &\quad (\geq 0 \text{ } PermitsCreate.BusinessActivity) \\
 &\quad (\geq 0 \text{ } PermitsDelete.BusinessActivity)
 \end{aligned}$$

For the purpose of this paper, Information and knowledge are the primary resources pertinent to the problem domain. This provides the definition,

$$\begin{aligned}
 &Information \subseteq Resource \\
 &Knowledge \subseteq Resource
 \end{aligned}$$

These definitions comprise “TBox” terminology for the proposed IT artifact including primitive concepts and their relationships. An “ABox” contains descriptions of individual instances. Specific instance level descriptions, using the TBox, provide illustrative examples for verification, refinement and for implementation of the semantic data models. These form the DL-based knowledge representation system used to reason about the problem domain. DL derives descriptive power through complex concepts descriptions comprised of concept constructors and atomic concepts and relationships. Terminological axioms comprising definitions and descriptions of problem domain concepts further describe the relationships between concepts and roles.

## Evaluation Design

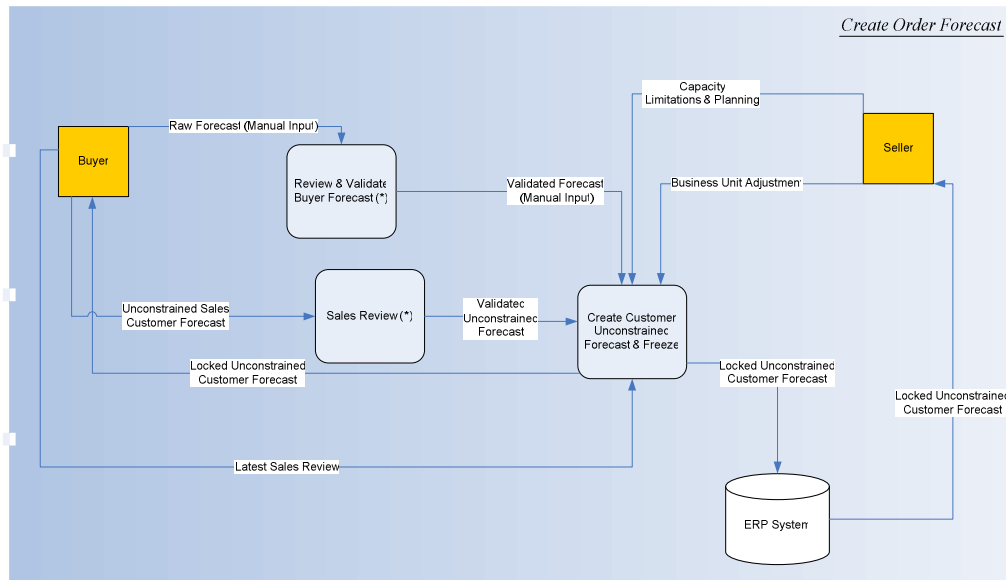
A design artifact must be evaluated to demonstrate its utility, quality, and efficacy. Hevner et al. (2004) state that evaluation methods available in the knowledge base may be used to rigorously evaluate a designed IT artifact. Hevner et al. (2004) suggest that the nature of the problem, characteristics of the artifact, and available resources dictate the selection of the evaluation method. The goal of the evaluation is to establish that the design artifact fulfills the requirements and constraints of the problem domain and therefore that it is complete and effective. Here, to evaluate the proposed IT artifact, we apply a descriptive evaluation method. Specifically, we use an *Order Forecast Business Process* from a large organization as example to illustrate the atomic concepts, their relationships and information and knowledge flows.

### Descriptive Evaluation

Given that industry standards lack the nuances of the real world, we include a case study to evaluate our proposed IT artifact. The researchers with the collaboration of Supply Chain and IT senior managers from Organization A identified a core business processes that exhibits the characteristics of our problem domain. Such a business process requires the exchange of information and knowledge within and across organizations of an extended enterprise while the seamless and secure flow of information and knowledge is guaranteed.

### Organization A<sup>1</sup>

Organization A is in the semiconductor industry. It manufactures main components for the mobile and wireless communication industry. Organization A has over 3,000 employees and a volume of sales over \$8 million for the fiscal year of 2005. An analysis of Organization A's order forecast business process reveals several issues. First, manual business activities, such as review and validation of buyer forecast and sales review, and business inputs, such as raw forecast data and validated forecast data, could generate several errors and delay the generation of demand forecast. Second, even though Organization A uses SKUs to identify their products, many inconsistencies with buyers' orders arise from the existence of various semantic conflicts. To solve this problem, Organization A utilizes humans that have *component knowledge* so that semantic mismatches can be solved. Finally, given that the order forecast business process still involves manual activities and inputs, the enforcement of Organization A's security policies is difficult to attain. By interviewing the CIO and Senior Managers, we collected information and documentation about the *Order Forecast Business Process*, which is presented in figure 3.



**Figure 3. Order Forecast Business Process (\* Manual Data source// Manual Process)**

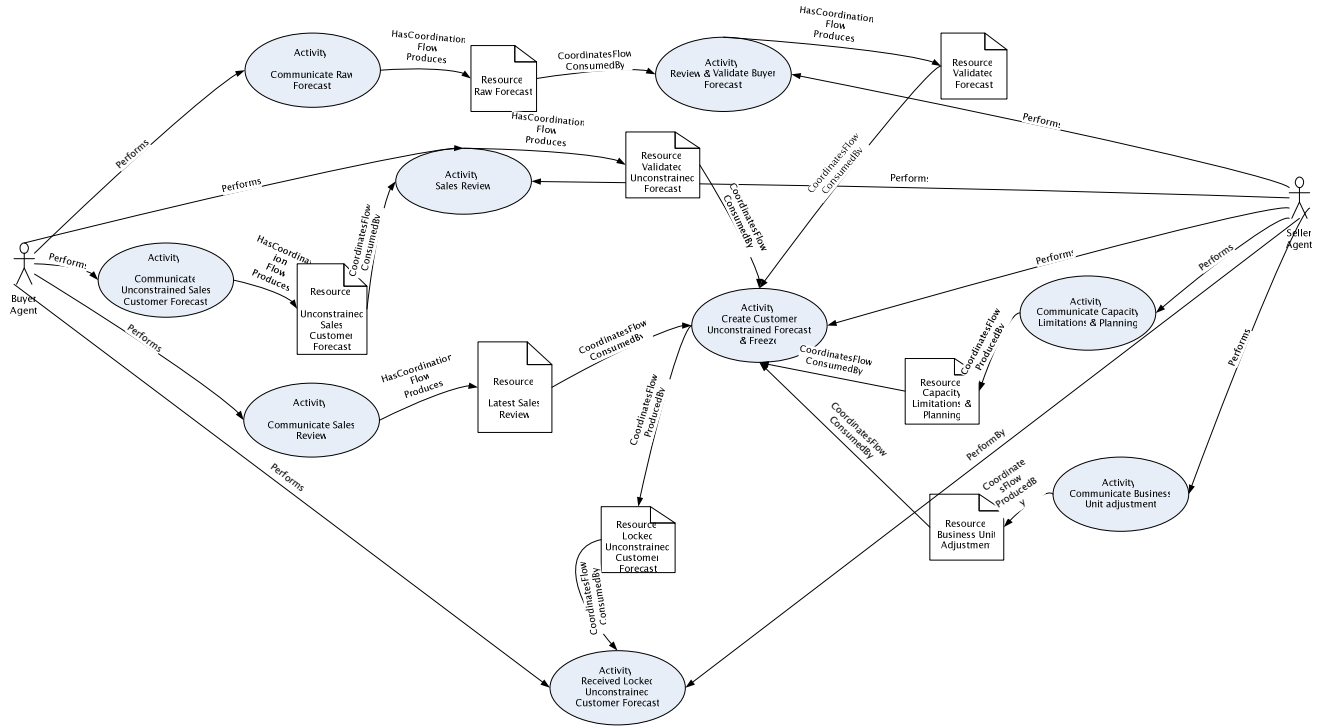
Applying the atomic concepts from the meta-design to analyze the *Order Forecast Business* process allows us to identify the following atomic concepts:

- i) Business Enterprise: Buyer and Seller
- ii) Business Activities: Communicate Raw Forecast; Communicate Unconstrained Sales Customer Forecast; Communicate Sales Review; Communicate Capacity Limitation and Planning; Communicate Business Adjustment; Create Unconstrained Forecast and Freeze; Review and Validate Buyer Forecast; Review Sales; Receive Locked Unconstrained Customer Forecast
- iii) Resources: Raw Forecast; Unconstrained Sales Customer Forecast; Locked Unconstrained Customer Forecast; Sales Review; Validated Forecast; Validated Unconstrained Forecast; Capacity Limitation and Planning Data; Business Unit Adjustment.

Figure 4 shows how the *Create Order Forecast* can be mapped using the semantic activity-resource coordination approach of proposed IT artifact.

<sup>1</sup> The company's name has been disguised to protect its identity





**Figure 4. Semantic Activity-Resource Coordination For Create Order Forecast Business Process**

In addition, we gathered information about the roles and permissions that the different actors have in the *Create Order Forecast* process and after analyzing them using RBAC (Sandhu et. al, 1996), we suggest, in Table 2, the role-activity-resource permissions.

Following, we provide the ontological engineering using DL-based definitions for the activity resource coordination for the demand forecasting process of *Organization A*. As established earlier, we utilize Description logics as the knowledge representation formalism for expressing structured knowledge in a format that is amenable for normative reasoning by intelligent software agents. Understanding the inherent relationships among business processes within and between organizations is a key topic of the information systems field. It is important to highlight that these demand requirement characteristics are intended to serve as examples and they are not exhaustive.

$BuyerRole \sqsubseteq$   
 $(=1 \text{ isRepresentedBy.BuyerAgent}) \wedge$   
 $(=1 \text{ Performs.CommunicateRawForecast}) \wedge$   
 $(=1 \text{ Performs.CommunicateUnconstrainedSalesCustomerForecast}) \wedge$   
 $(=1 \text{ Performs.CommunicateSalesReview}) \wedge$   
 $(=1 \text{ Performs.SalesReview})$

A buyer agent represents a buyer business enterprise as follows:

$BuyerAgent \sqsubseteq$   
 $(=1 \text{ Represents.Buyer}) \wedge$   
 $(=1 \text{ Fulfills.BuyerRole})$

A seller agent represents a seller business enterprise as follows:

$SellerRole \subseteq$   
 $(=1 \text{ isRepresentedBy.SellerAgent}) \wedge$   
 $(=1 \text{ Performs.CommunicateCapacityLimitationandPlanning}) \wedge$   
 $(=1 \text{ Performs.CommunicateBusinessAdjustment}) \wedge$   
 $(=1 \text{ Performs.Review\&ValidateBuyerForecast}) \wedge$   
 $(=1 \text{ Performs.ReceiveLockedUnconstrainedCustomerForecast}) \wedge$   
 $(=1 \text{ Performs.CreateUnconstrainedForecast\&Freeze})$

$SellerAgent \subseteq$   
 $(=1 \text{ Represents.Seller}) \wedge$   
 $(=1 \text{ Fulfills.SellerRole}) \wedge$

**Table 2. RBAC for Role-Activity-Resource Permissions for the *Create Order Forecast* Business Process**

Role	Fulfilled by	Business Activity	Permission Type (Write, Read, Create, Delete)	Resource
<b>BuyerRole</b>	Buyer Agent	Communicate Raw Forecast	Read	Raw Forecast
		Communicate Unconstrained Sales Customer Forecast	Read/Write	Unconstrained Sales Customer Forecast
		Communicate Sales Review	Read/Write	Latest Sales Review
		Sales Review	Read/Write	Unconstrained Sales Customer Forecast
			Write	Validate Unconstrained Forecast
<b>SellerRole</b>	Seller Agent	Communicate Capacity Limitation Planning	Read/Write	Capacity Limitation & Planning
		Communicate Business Adjustment	Read/Write	Business Unit Adjustment
		Review & Validate Buyer Forecast	Read	Raw Forecast
			Read/Write	Validated Forecast
		Receive Locked Unconstrained Customer Forecast	Read	Locked Unconstrained Customer Forecast
		Create Unconstrained Forecast & Freeze	Read	Validate Forecast Order Forecast Validate Unconstrained Forecast Capacity Limitation & Planning Business Unit Adjustments Locked Unconstrained Customer Forecast
			Write/Create	Locked Unconstrained Customer Forecast

Buyers communicate their *RawForecast* Data using standardized ontology for specifying the resource.

$RawForecast \subseteq (Resource) \wedge$   
 $(=1 \text{ IsOwnedBy.Buyer}) \wedge$   
 $(=1 \text{ hasID.I}) \wedge$   
 $(=1 \text{ CoordinatesFlowProducedBy.CommunicateRawForecast}) \wedge$   
 $(=1 \text{ CoordinatesFlowConsumedBy.Review\&ValidateBuyerForecast}) \wedge$   
 $(=1 \text{ Permits.CommunicateRawForecast}) \wedge$   
 $(=1 \text{ Permits.Review\&ValidateBuyerForecast})$

The buyer agent communicates *RawForecast* to coordinate the *Create Unconstrained Forecast and Freeze* activity.

$CommunicateRawForecast \subseteq (BusinessActivity) \wedge$   
 $(=1 \text{ IsPerformedby.BuyerRole}) \wedge$   
 $(=1 \text{ HasCoordinationFlowProduces.RawForecast}) \wedge$   
 $(=1 \text{ HasPermissionRead.RawForecast}) \wedge$   
 $(=1 \text{ HasPermissionWrite.RawForecast})$

Buyers communicate their *UnconstrainedSalesCustomerForecast* using standardized ontology for specifying the resource.

$$\begin{aligned} & \text{UnconstrainedSalesCustomerForecast} \sqsubseteq (\text{Resource}) \wedge \\ & (= 1 \text{ IsOwnedBy} \cdot \text{Buyer}) \wedge \\ & (= 1 \text{ hasID} \cdot 2) \wedge \\ & (= 1 \text{ CoordinatesFlowProducedBy} \cdot \\ & \quad \text{CommunicateUnconstrainedSalesCustomerForecast}) \wedge \\ & (= 1 \text{ CoordinatesFlowConsumedBy} \cdot \text{SalesReview}) \wedge \\ & (= 1 \text{ Permits} \cdot \text{CommunicateUnconstrainedSalesCustomerForecast}) \wedge \\ & (= 1 \text{ Permits} \cdot \text{SalesReview}) \end{aligned}$$

The buyer agent communicates *UnconstrainedSalesCustomerForecast* to coordinate the *SalesReview* activity.

$$\begin{aligned} & \text{CommunicateUnconstrainedSalesCustomerForecast} \sqsubseteq (\text{BusinessActivity}) \wedge \\ & (= 1 \text{ IsPerformedby} \cdot \text{BuyerRole}) \wedge \\ & (= 1 \text{ HasCoordinationFlowProduces} \cdot \text{UnconstrainedSalesCustomerForecast}) \wedge \\ & (= 1 \text{ HasPermissionRead} \cdot \text{UnconstrainedSalesCustomerForecast}) \wedge \\ & (= 1 \text{ HasPermissionWrite} \cdot \text{UnconstrainedSalesCustomerForecast}) \end{aligned}$$

Buyers communicate their *LatestSalesReview* using standardized ontology for specifying the resource.

$$\begin{aligned} & \text{LatestSalesReview} \sqsubseteq (\text{Resource}) \wedge \\ & (= 1 \text{ IsOwnedBy} \cdot \text{Buyer}) \wedge \\ & (= 1 \text{ hasID} \cdot 3) \wedge \\ & (= 1 \text{ CoordinatesFlowProducedBy} \cdot \text{CommunicateSalesReview}) \wedge \\ & (= 1 \text{ CoordinatesFlowConsumedBy} \cdot \text{CreateUnconstrainedForecast\&Freeze}) \wedge \\ & (= 1 \text{ Permits} \cdot \text{CommunicateSalesReview}) \wedge \\ & (= 1 \text{ Permits} \cdot \text{CreateUnconstrainedForecast\&Freeze}) \end{aligned}$$

The buyer agent Communicates Sales Review to coordinate the *Create Unconstrained Forecast and Freeze* activity.

$$\begin{aligned} & \text{CommunicatesSalesReview} \sqsubseteq (\text{BusinessActivity}) \wedge \\ & (= 1 \text{ IsPerformedby} \cdot \text{BuyerRole}) \wedge \\ & (= 1 \text{ HasCoordinationFlowProduces} \cdot \text{LatestSalesReview}) \wedge \\ & (= 1 \text{ HasPermissionRead} \cdot \text{LatestSalesReview}) \wedge \\ & (= 1 \text{ HasPermissionWrite} \cdot \text{LatestSalesReview}) \end{aligned}$$

Buyers represent their *ValidatedUnconstrainedForecast* using standardized ontology for specifying the resource.

$$\begin{aligned} & \text{ValidatedUnconstrainedForecast} \sqsubseteq (\text{Resource}) \wedge \\ & (= 1 \text{ IsOwnedBy} \cdot \text{Buyer}) \wedge \\ & (= 1 \text{ hasID} \cdot 4) \wedge \\ & (= 1 \text{ CoordinatesFlowProducedBy} \cdot \text{SalesReview}) \wedge \\ & (= 1 \text{ CoordinatesFlowConsumedBy} \cdot \text{CreateUnconstrainedForecast\&Freeze}) \wedge \\ & (= 1 \text{ Permits} \cdot \text{SalesReview}) \wedge \\ & (= 1 \text{ Permits} \cdot \text{CreateUnconstrainedForecast\&Freeze}) \end{aligned}$$

The buyer agent performs Sales review to coordinate the *Create Unconstrained Forecast and Freeze* activity.

$$\begin{aligned} & \text{SalesReview} \sqsubseteq (\text{BusinessActivity}) \wedge \\ & (= 1 \text{ IsPerformedby} \cdot \text{BuyerRole}) \wedge \\ & (= 1 \text{ HasCoordinationFlowProduces} \cdot \text{ValidatedUnconstrainedForecast}) \wedge \\ & (= 1 \text{ HasCoordinationFlowConsumes} \cdot \text{UnconstrainedSalesCustomerForecast}) \wedge \\ & (= 1 \text{ HasPermissionRead} \cdot \text{UnconstrainedSalesCustomerForecast}) \wedge \\ & (= 1 \text{ HasPermissionRead} \cdot \text{ValidatedUnconstrainedForecast}) \wedge \\ & (= 1 \text{ HasPermissionWrite} \cdot \text{ValidatedUnconstrainedForecast}) \end{aligned}$$

Sellers communicate their capacity limitations & planning using standardized ontology for specifying the resource.

$CapacityLimitation\&Planning \sqsubseteq (Resource) \wedge$   
 $(= 1 IsOwnedBy.Seller) \wedge$   
 $(= 1 hasID .5) \wedge$   
 $(= 1 CoordinatesFlowProducedBy.CommunicateCapLimitation\&Planning) \wedge$   
 $(= 1 CoordinatesFlowConsumedBy.CreateUnconstrainedForecast\&Freeze) \wedge$   
 $(= 1 Permits . CommunicateCapLimitation\&Planning) \wedge$   
 $(= 1 Permits . CreateUnconstrainedForecast\&Freeze)$

The seller agent communicates capacity limitations and planning to coordinate the *Create Unconstrained Forecast and Freeze* activity.

$CommunicateCapacityLimitation\&Planning \sqsubseteq (BusinessActivity) \wedge$   
 $(= 1 IsPerformedby.SellerRole) \wedge$   
 $(= 1 HasCoordinationFlowProduces.CapacityLimitation\&Planning) \wedge$   
 $(= 1 HasPermissionRead. CapacityLimitation\&Planning) \wedge$   
 $(= 1 HasPermissionWrite. CapacityLimitation\&Planning)$

Sellers communicate their *BusinessUnitAdjustments* using standardized ontology for specifying the resource.

$BusinessUnitAdjustments \sqsubseteq (Resource) \wedge$   
 $(= 1 IsOwnedBy.Buyer) \wedge$   
 $(= 1 hasID .6) \wedge$   
 $(= 1 CoordinatesFlowProducedBy.CommunicateBusinessUnitAdjustments) \wedge$   
 $(= 1 CoordinatesFlowConsumedBy.CreateUnconstrainedForecast\&Freeze) \wedge$   
 $(= 1 Permits . CommunicateBusinessUnitAdjustments) \wedge$   
 $(= 1 Permits . CreateUnconstrainedForecast\&Freeze)$

The seller agent communicates *BusinessUnitAdjustments* data to coordinate the *Create Unconstrained Forecast and Freeze* activity.

$CommunicateBusinessUnitAdjustments \sqsubseteq (BusinessActivity) \wedge$   
 $(= 1 IsPerformedby.SellerRole) \wedge$   
 $(= 1 HasCoordinationFlowProduces. HistoricalDemandShipment) \wedge$   
 $(= 1 HasPermissionRead. BusinessUnitAdjustments) \wedge$   
 $(= 1 HasPermissionWrite. BusinessUnitAdjustments)$

Sellers communicate their Validated Forecast data using standardized ontology for specifying the resource.

$ValidatedForecast \sqsubseteq (Resource) \wedge$   
 $(= 1 IsOwnedBy.Seller) \wedge$   
 $(= 1 hasID .7) \wedge$   
 $(= 1 CoordinatesFlowProducedBy.Review\&ValidateBuyerForecast) \wedge$   
 $(= 1 CoordinatesFlowConsumedBy.CreateUnconstrainedForecast\&Freeze) \wedge$   
 $(= 1 Permits . Review\&ValidateBuyerForecast) \wedge$   
 $(= 1 Permits . CreateUnconstrainedForecast\&Freeze)$

The seller agent performs the *Review and Validate Buyer Forecast* activity to coordinate the *Create Order Forecast* activity.

$Review\&ValidateBuyerForecast \sqsubseteq (BusinessActivity) \wedge$   
 $(= 1 IsPerformedby.SellerRole) \wedge$   
 $(= 1 HasCoordinationFlowProduces. ValidatedForecast) \wedge$   
 $(= 1 HasPermissionRead. ValidatedForecast) \wedge$   
 $(= 1 HasPermissionWrite. ValidatedForecast)$

The seller agent performs the *Create Unconstrained Forecast and Freeze* activity to coordinate order forecast.

$$\begin{aligned}
& \text{CreateUnconstrainedForecast\&Freeze} \sqsubseteq (\text{BusinessActivity}) \wedge \\
& (= 1 \text{ IsPerformedby.SellerRole}) \wedge \\
& (= 1 \text{ HasCoordinationFlowConsumes. ValidatedUnconstrainedForecast}) \wedge \\
& (= 1 \text{ HasCoordinationFlowConsumes. CapacityLimitation\&Planning}) \wedge \\
& (= 1 \text{ HasCoordinationFlowConsumes. BusinessUnitAdjustments}) \wedge \\
& (= 1 \text{ HasPermissionRead. ValidatedForecast}) \wedge \\
& (= 1 \text{ HasPermissionRead. OrderForecast}) \wedge \\
& (= 1 \text{ HasPermissionRead. ValidatedUnconstrainedForecast}) \wedge \\
& (= 1 \text{ HasPermissionRead. CapacityLimitation\&Planning}) \wedge \\
& (= 1 \text{ HasPermissionRead. BusinessUnitAdjustments}) \wedge \\
& (= 1 \text{ HasPermissionRead. LockedUnconstrainedCustomerForecast}) \wedge \\
& (= 1 \text{ HasPermissionWrite. LockedUnconstrainedCustomerForecast}) \wedge \\
& (= 1 \text{ HasPermissionCreate. LockedUnconstrainedCustomerForecast})
\end{aligned}$$

Sellers create their *Locked Unconstrained Customer Forecast* using standardized ontology for specifying the resource.

$$\begin{aligned}
& \text{LockedUnconstrainedCustomerForecast} \sqsubseteq (\text{Resource}) \wedge \\
& (= 1 \text{ IsOwnedBy.Seller}) \wedge \\
& (= 1 \text{ hasID.8}) \wedge \\
& (= 1 \text{ CoordinatesFlowProducedBy.CreateUnconstrainedForecast\&Freeze}) \wedge \\
& (= 1 \text{ CoordinatesFlowConsumedBy.ReceiveLockedUnconstrainedCustomerForecast}) \wedge \\
& (= 1 \text{ Permits.CreateUnconstrainedForecast\&Freeze}) \wedge \\
& (= 1 \text{ Permits.ReceiveLockedUnconstrainedCustomerForecast}) \wedge \\
& (= 1 \text{ hasCharacteristics.ForecastType}) \wedge \\
& (= 1 \text{ hasCharacteristics.GenerationDate}) \wedge \\
& (= 1 \text{ hasCharacteristics.StartDate}) \wedge \\
& (= 1 \text{ hasCharacteristics.EndDate}) \wedge \\
& (= 1 \text{ hasCharacteristics.ProductID}) \wedge \\
& (= 1 \text{ hasCharacteristics.Quantity}) \wedge \\
& (= 1 \text{ hasCharacteristics.ChangeRestrictionIndicator})
\end{aligned}$$

Finally, the seller agent coordinates the receive *LockedUnconstrainedCustomerForecast* activity.

$$\begin{aligned}
& \text{RecieveLockedUnconstrainedCustomerForecast} \sqsubseteq (\text{BusinessActivity}) \wedge \\
& (= 1 \text{ IsPerformedby.SellerRole}) \wedge \\
& (= 1 \text{ HasCoordinationFlowConsumes.LockedUnconstrainedCustomerForecast}) \wedge \\
& (= 1 \text{ HasPermissionRead.LockedUnconstrainedCustomerForecast})
\end{aligned}$$

We have illustrated how the meta-design can be applied to a real business process and shown the feasibility of using emerging technologies to solve semantic conflict issues, to prevent unauthorized access to resources, to foster knowledge exchange, and to integrate heterogeneous systems in an extended enterprise. In addition, the above DL formalisms provide computationally feasible knowledge representation (KR) mechanisms for business processes. This forms the basis for the development of machine interpretable knowledge representation in the OWL-DL format. All DL knowledge representations presented in this paper have been developed, validated and checked for consistency using Protégé and Racer. These tools generate OWL-DL knowledge representations essential to development of the proposed IT artifact incorporating reasoning and inference mechanisms based on DL-formalism. The use of standard semantic models such as W3C's OWL (Web Ontology Language) and OWL-DL transforms this approach into a truly implementable framework without losing theoretical robustness. These provide the basis for practitioners to initiate further development and evaluation of secure semantic eBusiness processes that are semantically rich, highly coordinated and seamlessly integrated.

## Conclusions

We started with the premises that information and knowledge sharing in an extended enterprise occurs in a Business Process context (Raghu and Vinze, 2007; Singh and Salam, 2006) and that knowledge is a strategic resource (Grant, 1996) that must be shared to be useful and applicable for inter-organizational business processes (Raghu and Vinze, 2007). Then we developed an IT artifact that allows for security of information and knowledge resources and system integration; so that knowledge exchange in an extended enterprise can be seamlessly and securely accomplished. Here, information and knowledge resources are expressed in standardized, computationally-feasible knowledge representation languages and shared in a secure and coordinated manner. We provide mechanisms to incorporate the systematic representation of *component knowledge* (Tallman et al, 2004), *process knowledge* (van der Aalst and Kumar, 2003) and *security knowledge* (Sandhu, 1996) in the design of secure and coordinated eBusiness processes.

The proposed IT artifact enables the secure exchange of explicit and codified knowledge by employing semantics and reasoning. Semantic technologies, including Description Logics (DL) and Web Ontology Language (OWL), provide computationally-feasible knowledge representation (KR) mechanisms for business processes. We provided atomic concepts and relationships using DL formalism for theoretical soundness. This forms the basis for the development of machine interpretable knowledge representation in the OWL-DL format. All DL knowledge representations presented in this paper have been developed, validated and checked for consistency using Protégé and Racer. These tools generate OWL-DL knowledge representations essential to development of the proposed IT artifact incorporating reasoning and inference mechanisms based on DL-formalism.

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